

MICHIGAN POTASH OPERATING, LLC

August 12th, 2015

Ms. Janette Hansen
Class III Area Permitting
UIC Branch (WU-16J)
US EPA Region 5
77 W. Jackson Blvd
Chicago, IL 60604-3590

RE: INQUIRY, CORE CHEMICAL ANALYSIS
CLASS III AREA PERMIT, OSCEOLA AND MECOSTA COUNTY MICHIGAN

Sent: VIA E-MAIL

Dear Ms. Hansen:

In response to your inquiry concerning the chemical analysis of the MPO Class III Area 'potash', please find attached, compiled for your reference, the following:

- (1) A photograph of Michigan Sylvinite ore in the Class III Area; which has been taken alongside a Canadian sylvinite sample for comparative purposes; and
- (2) a visual explanation of that photograph; and
- (3) a chemical analysis of a core in the Class III Area, administered by the Michigan Geological Survey and an independent lab in Saskatchewan, Canada; and
- (4) a visual representation of those results; and
- (5) a presentation by the Michigan Geological Survey, with specific reference to chemical analysis performed under the Class III area.

In summary, the Michigan Deposit is principally KCl, NaCl, with very minor amounts of CaSO₄ (Anhydrite) and MgCl.

Please feel free to contact me directly with comments, questions, or concerns.


Sincerely,





Theodore Pagano, P.E., P.G.
Manager
Michigan Potash Operating LLC

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Ore	Equivalent K_2O
Sylvite	63.0 %
Langbeinite	22.6 %
Kainite	18.4 %
Carnallite	17.0 %
Polyhalite	15.5 %

 Michigan Potash
Ore is Pure
Sylvinite.

 Sylvinite is a
mixture of sylvite
(KCl) and halite
(NaCl).

 Michigan ore is the
purest Sylvinite in
the world.

Canadian Sylvinite

Michigan Sylvinite



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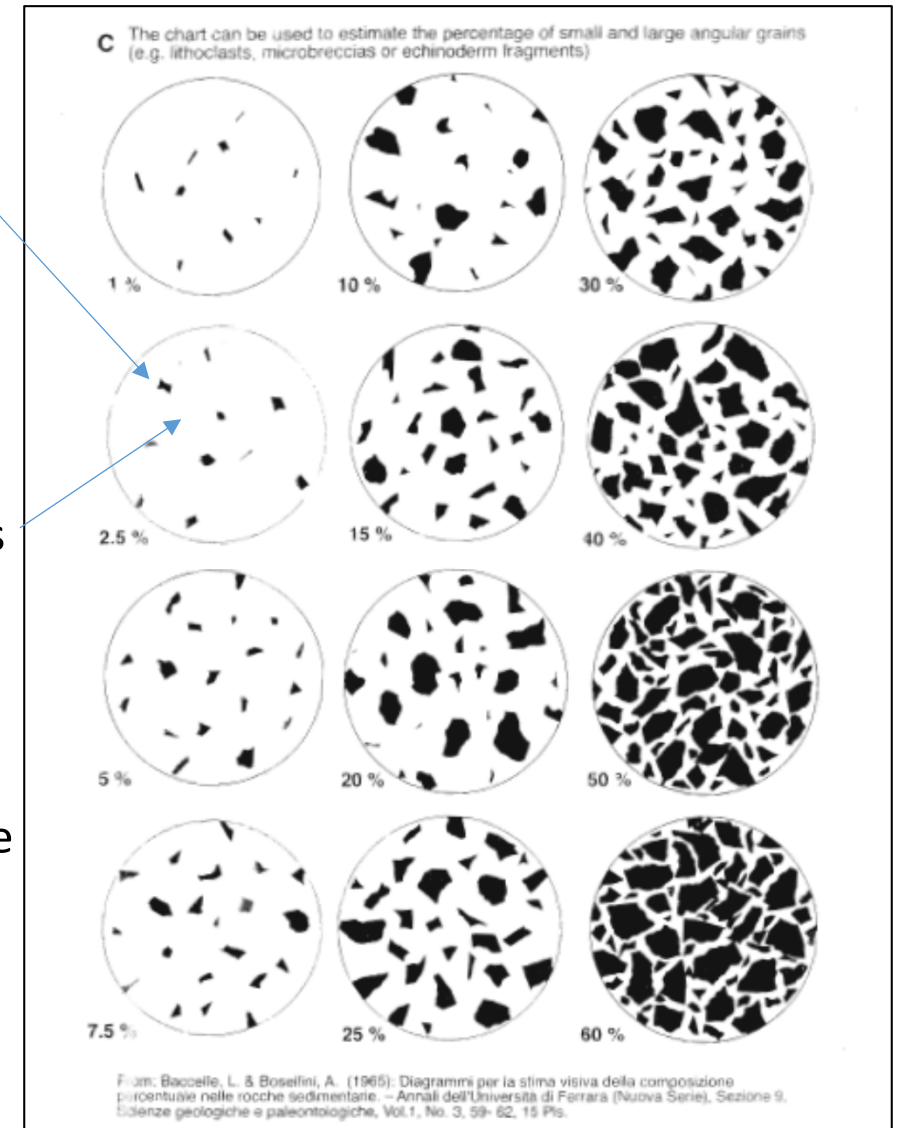
Canadian Sylvinitite

Michigan Sylvinitite

NaCl (Salt) Crystals
Have shape

KCl (Sylvite*) Crystals
are amorphous.

This photograph,
measures 70% Sylvite
(70% KCl).





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TYPE CORE CHEMICAL ANALYSIS

Description, Potash ICP2 Soluble	K ₂ O	Na ₂ O	MgO	CaO	S
Sample Identification	wt %	wt %	wt %	wt %	wt%
TYPE WELL 7651-7654	18.1	37.5	0.02	0.2	0.114
TYPE WELL 7654.5-7656.5	49.8	11.2	0.02	0.1	0.0444
TYPE WELL 7657-7659.5	43.5	16.1	0.02	0.11	0.0548
TYPE WELL 7660-7663	39.5	19.5	0.02	0.12	0.0542
TYPE WELL 7665-7667	40.3	18.4	0.02	0.2	0.106
TYPE WELL 7670-7673	39	19.8	0.05	0.19	0.097
TYPE WELL 7673-7675	27.4	29.9	0.04	0.23	0.122
TYPE WELL 7717.5-7720	41.2	17.5	0.04	0.34	0.192
TYPE WELL 7733-7735	16.7	38.5	0.02	0.38	0.222
TYPE WELL 7735-7736.5	20.4	35.6	0.01	0.43	0.266
TYPE WELL 7745.5 - 7747	15.3	39.4	0.03	0.27	0.167
TYPE WELL 7748.5-7749.5	17.5	38	0.04	0.31	0.189
TYPE WELL 7767-7769	23.2	32.4	0.2	0.13	0.273
TYPE WELL 7770.25-7770.75	0.79	52.5	0.04	0.23	0.152
TYPE WELL 7771.5-7773	32.3	25.6	0.02	0.16	0.0975
TYPE WELL 7773.5-7774.5	18.6	37.1	0.03	0.25	0.156
TYPE WELL 7773-7773.5	21.6	34.6	0.03	0.2	0.117
TYPE WELL 7773-7774.5	21.7	34.4	0.03	0.22	0.14
TYPE WELL 7775-7776	24.6	32	0.03	0.18	0.111
TYPE WELL 7776-7777	20.4	35.4	0.02	0.16	0.098
TYPE WELL 7755-7757	20.7	35.3	0.04	0.15	0.12

By: SRC Geoanalytical Laboratories


125 - 15 Innovation Blvd., Saskatoon, Saskatchewan, S7N 2X8

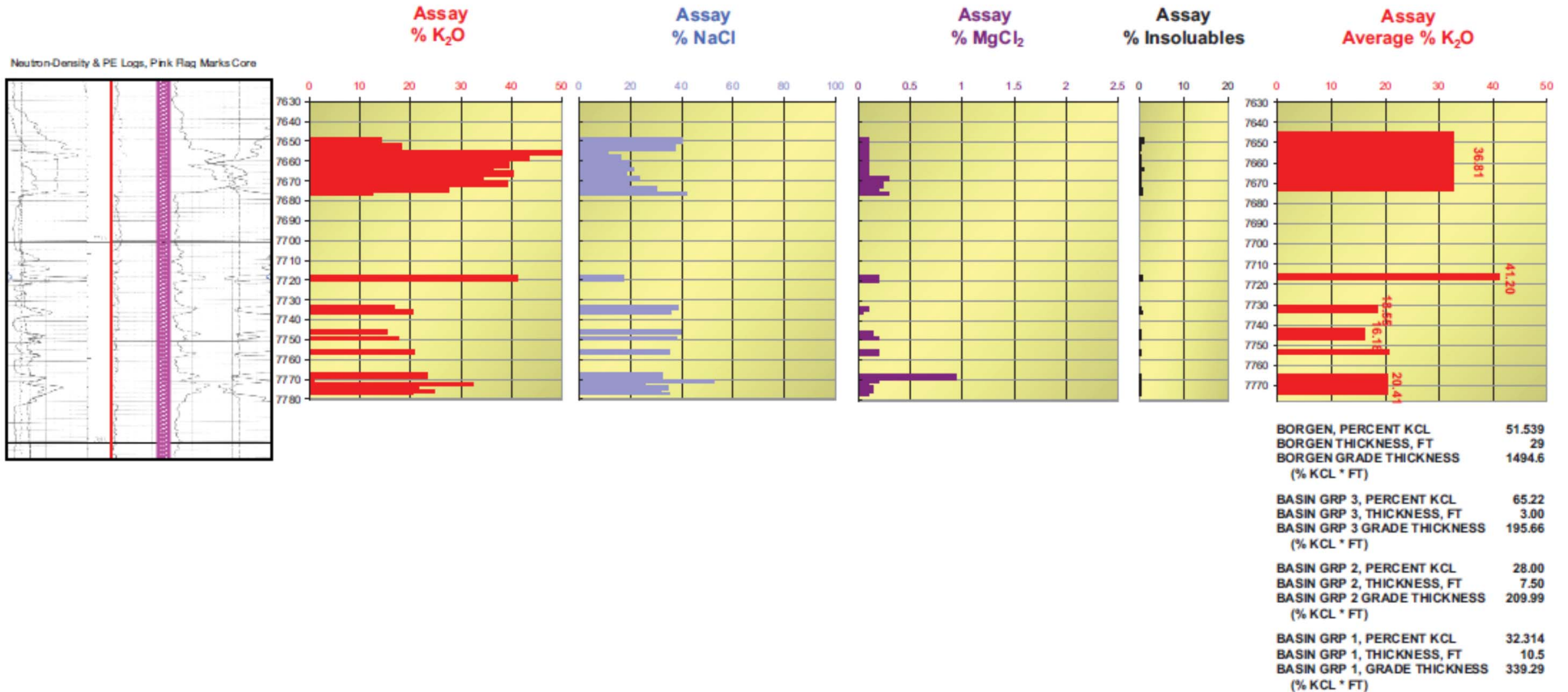
Tel: (306) 933-8118 Fax: (306) 933-8118 Email: geolab@src.sk.ca

Michigan Potash Company

ICP2 Soluble Results for Major Constituents

MICHIGAN POTASH OPERATING

 Type Well in the Class III Area



Occurrence of Potash-Bearing Strata (Sylvinite) in the Salina A-1 Evaporite in the Central Michigan Basin*

William B. Harrison, III¹

Search and Discovery Article #10652 (2014)**

Posted October 13, 2014

*Adapted from oral presentation given at AAPG 43rd Eastern Section Meeting, London, Ontario, Canada, September 27-30, 2014

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¹Michigan Geological Survey, Western Michigan University, Kalamazoo, MI (harrison@wmich.edu)

Abstract

Potash occurs in the deep, center of the Michigan basin and contained exclusively in the Salina A-1 Evaporite formation as Sylvinite in the middle or upper portions of the formation. The Potash occurs as Sylvite (in relatively pure beds as much as 30 feet thick or as Sylvite (KCl) intimately intermixed with Halite (NaCl) as Sylvinite. These deposits were first described by Dow Chemical Company scientists in the early 1970's, based on samples from a core in Midland County and nearby well Gamma Ray logs. The Potash zones are located between 7,000 and 9,000 feet deep and occur in all or parts of 17 counties in the northern half of Michigan's Lower Peninsula.

Commercial Potash mining in Michigan began at a solution mining facility near Hersey, Michigan in 1997. The plant was designed for production of 160,000 tons of Potash per year primarily from a 20-30 foot thick interval, near the top of the A-1 Evaporite, of relatively pure Potash locally known as the "Borgen Bed". The grade of this Potash deposit is one of the highest in the world at nearly 70% KCl by volume. It is also very pure containing negligible Carnallite and about 0.5% insolubles. Potash production at the Hersey mine ceased in 2013 although the facility still does produce Salt (NaCl).

In 2008, a significant collection of core from the A-1 Evaporite in the commercial mining area as well as throughout the northern half of Michigan was donated to Western Michigan University. The collection contained over 11,300 linear feet of conventional, 4-inch core sealed in plastic sleeves, from 77 different wells in nine counties. In addition to the cores, several hundred modern wireline logs are available from wells that pass through the Potash zone. Gamma Ray, Compensated Neutron and Lithodensity curves are all useful in defining the stratigraphic occurrence and approximate thickness of the Potash-bearing strata. The "Borgen Bed", near the top of the formation is widespread in the western portion of the area, whereas there is a sequence of thinner Sylvite and Sylvite/Halite interbeds in the middle of the formation to the eastern portion of the area.

By supplementing the core data with wireline logs, it can be estimated that Michigan's Potash deposits are contained in 17 counties in the central and northern part of the Michigan basin. Based on thickness of Sylvite intervals and grade values from core analysis, it is likely that commercial production can come from nine counties representing 2.9 million acres.

References Cited

- Anderson, R.J., and G.C. Egleson, 1970, Discovery of potash in the A-1 Salina salt in Michigan: in Forum on Geology of Industrial Minerals, Michigan Geological Survey Miscellany 1, p. 15-19.
- Burgess, R.J., and A.L. Benson, 1969, Exploration for Niagaran reefs in Michigan, Pts. 1-2: Oil and Gas Journal, v. 67/51, p. 80-82.
- Gill, D., 1977, The Bell River Mills Gas Field; Productive Niagaran Reefs Encased by Sabhka Deposits, Michigan Basin: Michigan Basin Geological Society, Special Paper #2, 118 p.
- Matthews, R.D., 1970, The distribution of Silurian potash in the Michigan Basin: in Kneller, W.A., ed., Sixth Forum on Geology of Industrial Minerals, Michigan Geological Survey Miscellaneous Paper 1, p. 20-33.
- Ritter, A.L., 2008, Evaluating the Controls on Reservoir Heterogeneity of Silurian Pinnacle Reefs, Michigan Basin: Thesis (MS), Western Michigan University, Kalamazoo, Michigan, 247 p.

Occurrence of Potash-bearing strata (Sylvinite) in the Salina A-1 Evaporite in the Central Michigan Basin

Dr. William B. Harrison, III

Michigan Geological Repository for Research and Education

Michigan Geological Survey

Western Michigan University

Eastern Section American Association of Petroleum Geologists

2014 Annual Meeting

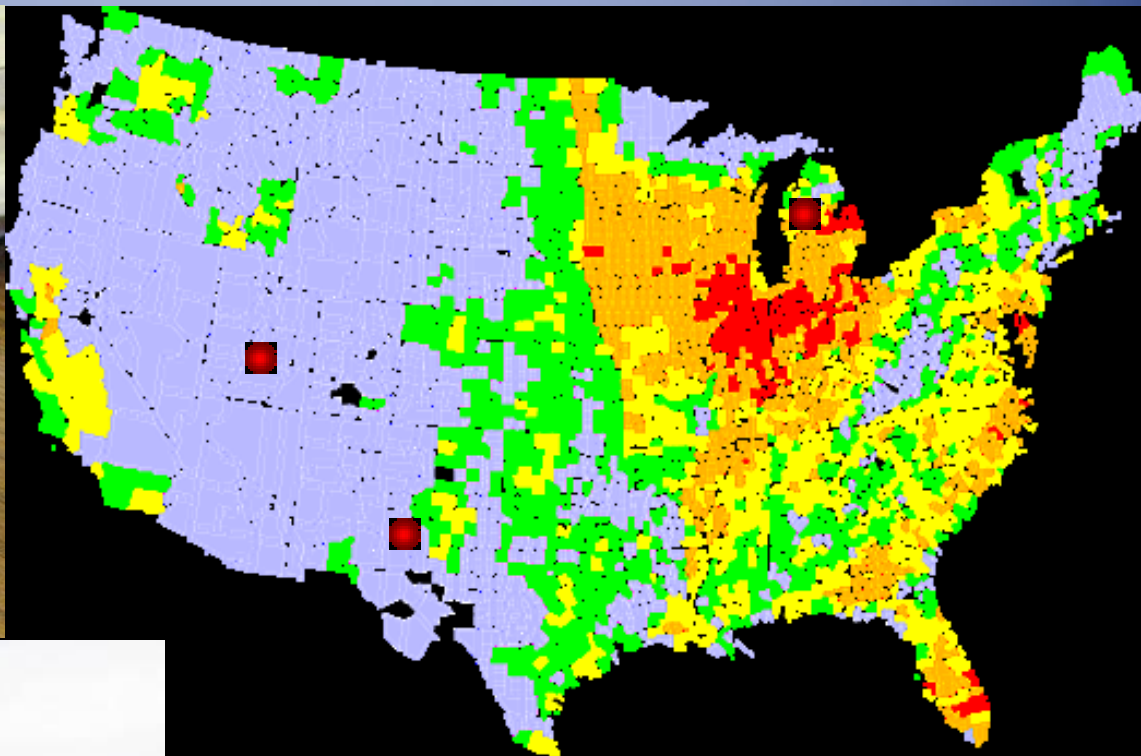
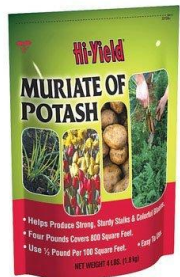
London, Ontario, Canada



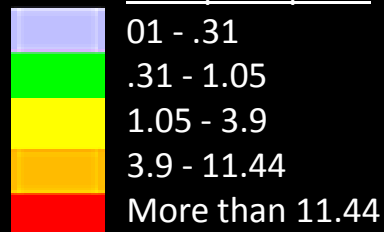
U.S. Potash Facts

- Potash (K_2O) refers to a group of potassium bearing minerals, the most common being potassium chloride (KCl). Potassium (K) is the seventh most common element in the earth's crust, and is found in every cell of plants and animals and is essential to their growth.
- 2012 U.S. Production – 900,000 tons
- 2012 production value - \$675 million (@\$750/ton)
- 2012 Imports – 4,000,000 tons
- Import Sources – Canada – 84%, Russia – 11%
- Potash produced in Michigan (recently closed), New Mexico, and Utah. Most production from New Mexico

U.S. Potash Demand for Agriculture



Tons per sq mile



Source: USGS

 US Potash Mining Locations

U.S. Potash Production and Consumption Statistics

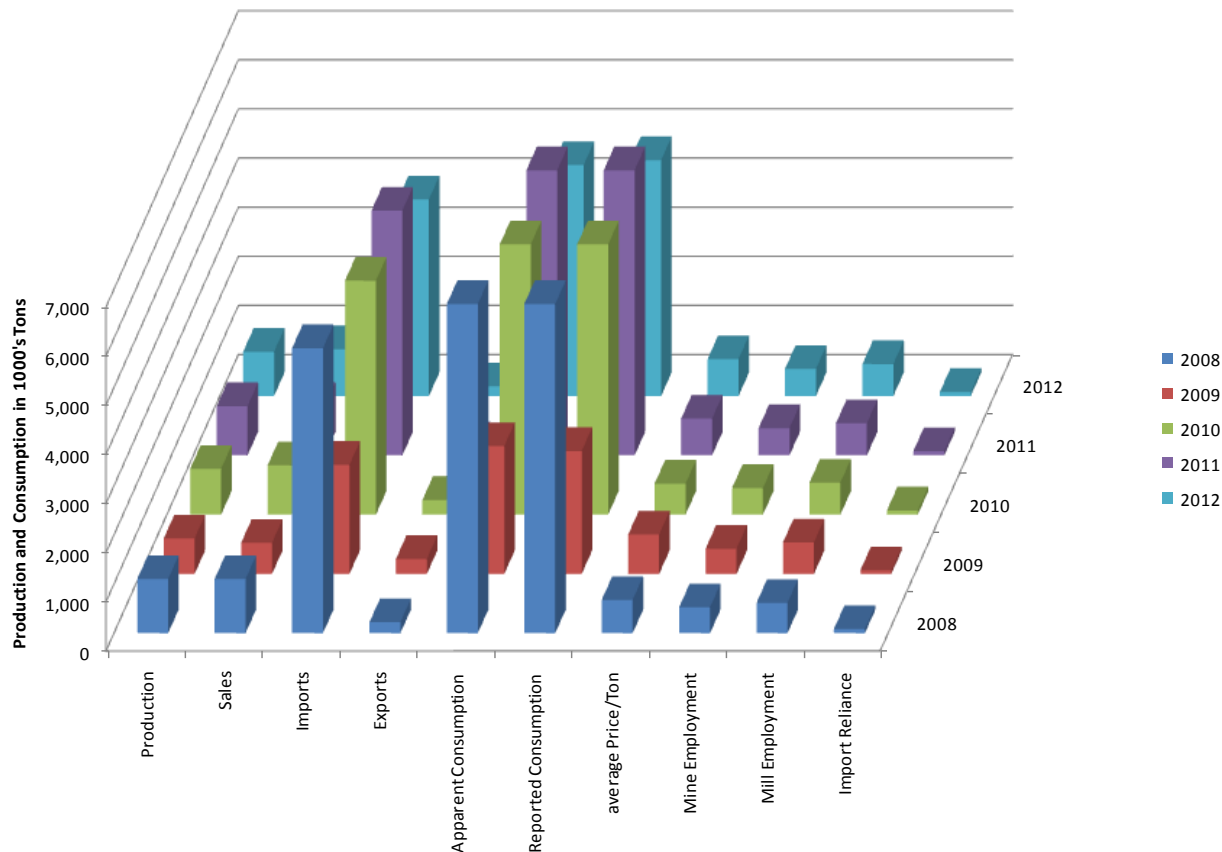


Underground Potash Mine
in Saskatchewan, Canada



Mosaic Michigan Potash
Solution Mine Hersey,
Osceola Co.

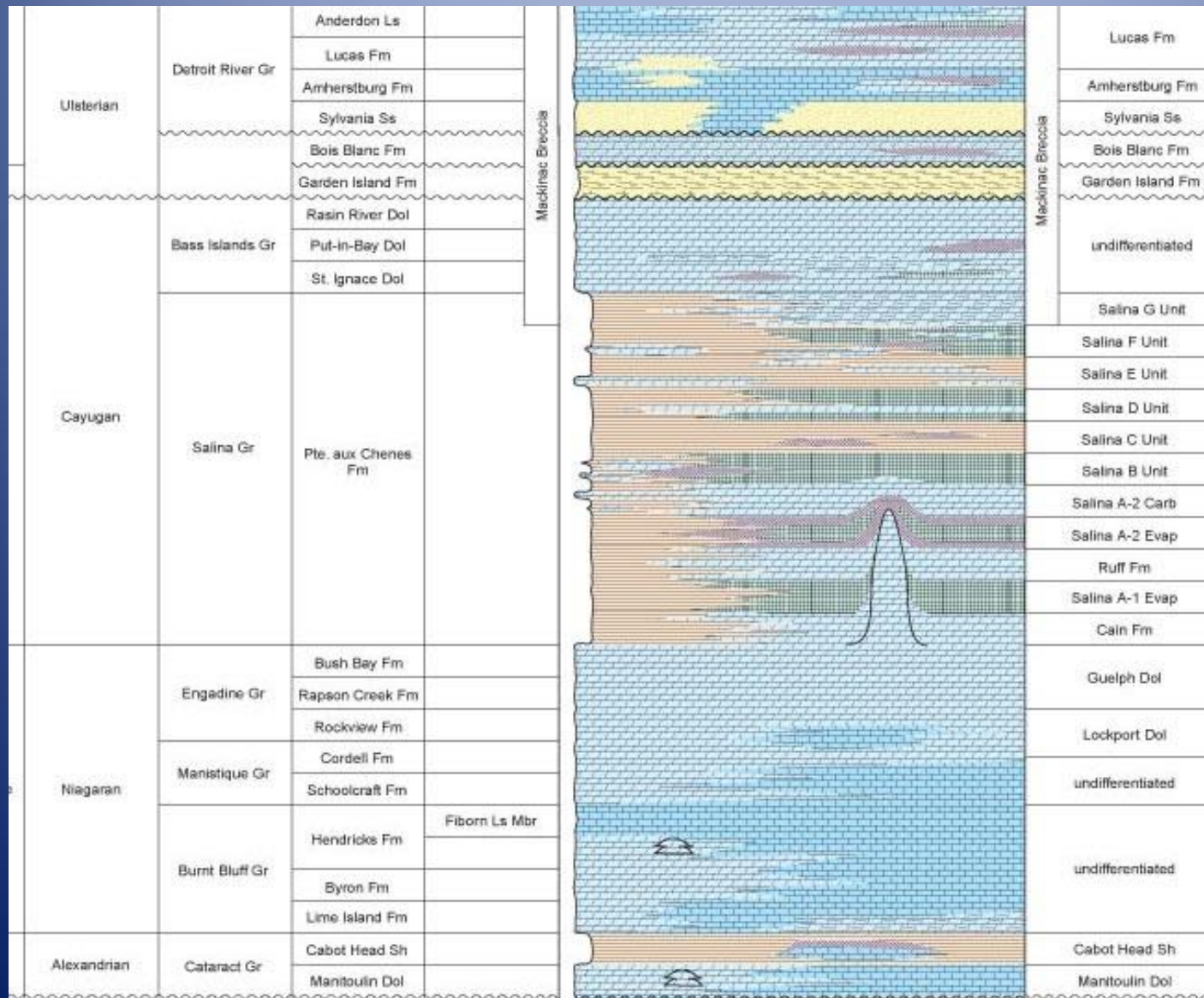
U.S. Potash Production and Consumption 2008-2012



Occurrence of Michigan Potash strata

- ❖ Contained exclusively in the Salina A-1 Salt Formation in the Michigan Basin
- Interbedded as relatively pure Sylvite (KCl) beds within Halite (NaCl) in the upper half of the formation
- Geographically located in basin center at depths between 7000 and 9000 feet deep
- Some Potash beds occur in all or parts of 17 counties, but commercial quantities may be limited to about 8 counties

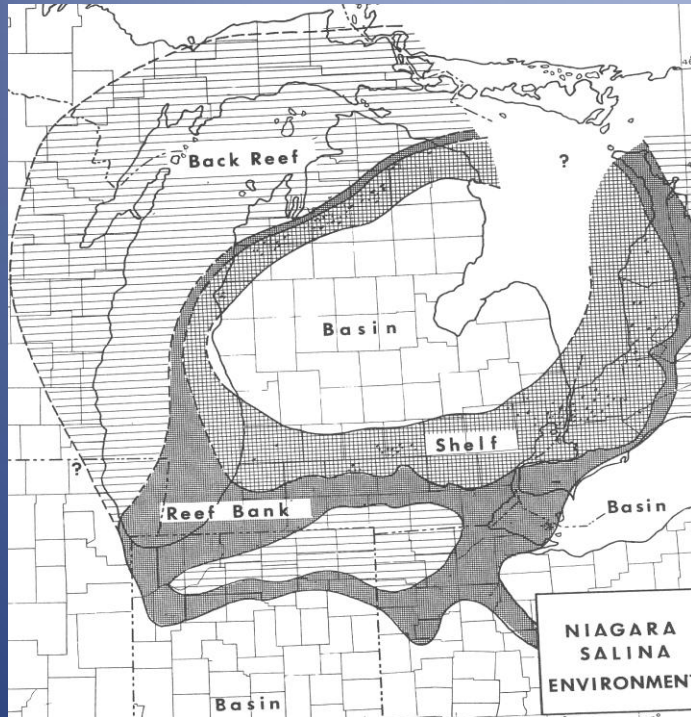
Michigan Stratigraphic Column



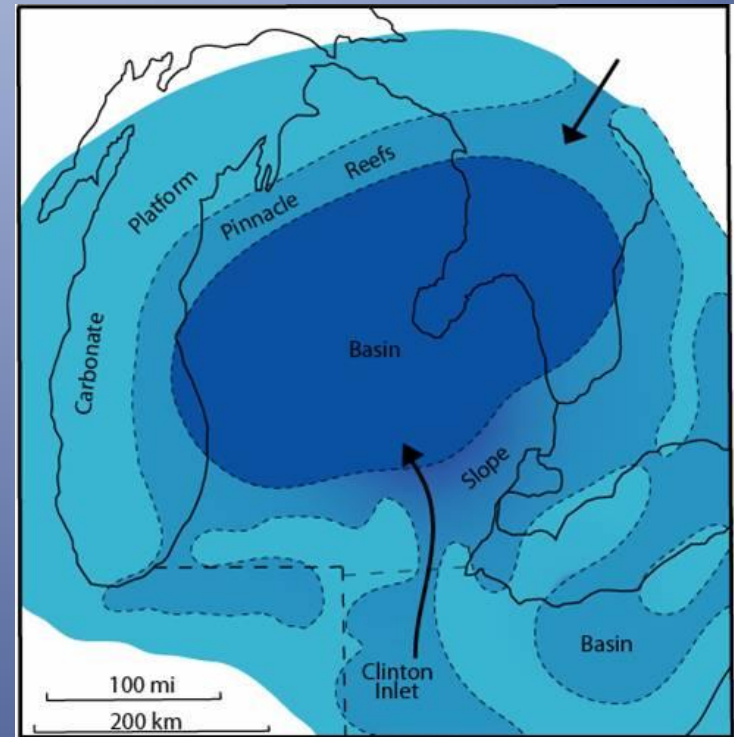
Restricted Marine Carbonates interbedded with Evaporites

Shallow Marine Shelf Carbonates capped by Reefs

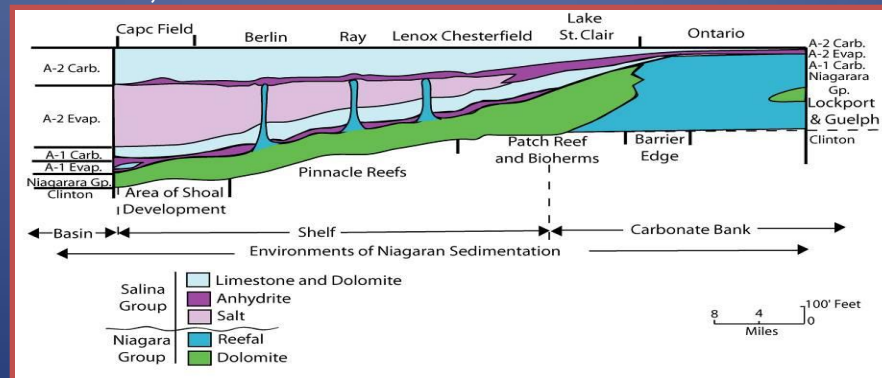
Distribution of Middle Silurian Environments, Michigan Basin



Gill, 1977



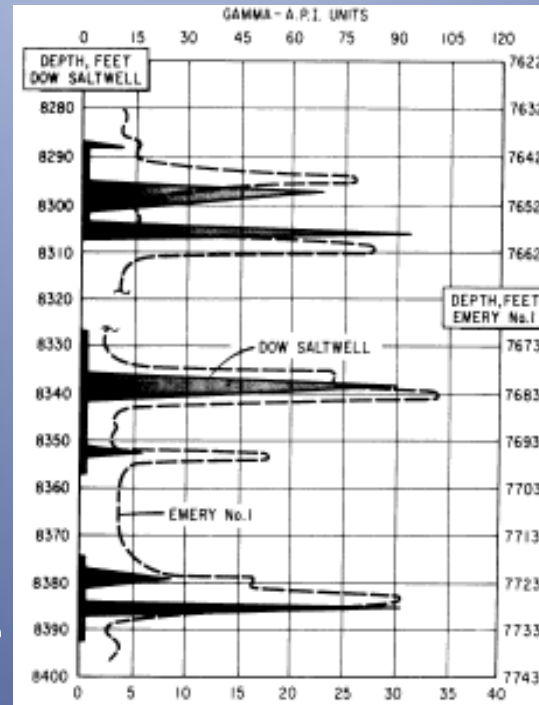
Ritter, 2008



Modified from Burgess and Benson, 1969

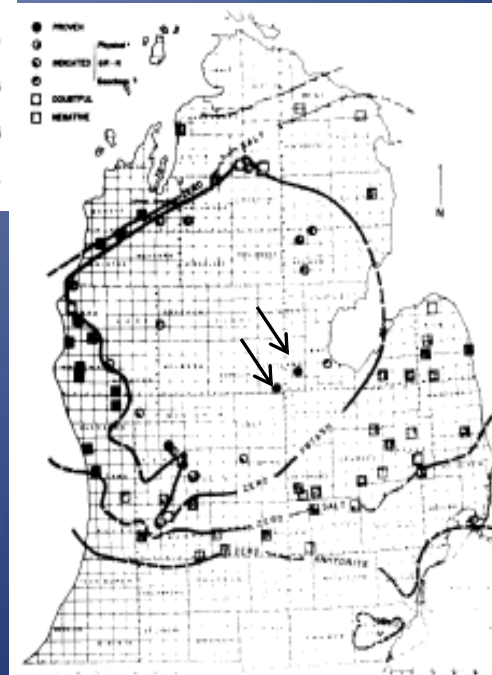
Historic Studies of Michigan Potash

- Dow Chemical Co. research group in late 1966 sampled core in Dow Chemical #8 Salt Well in Midland Co. Compared it to the Gamma Ray log of the Pure-Merton-Emery #1 well 11.4 miles to the SW
- Matthews, 1970 and Matthews and Egleson, 1973 mapped the distribution of Potash in the A-1 Salt using wireline logs and brine analyses
- Matthews, 1970 suggested that Potash occurred in parts of 22 counties covering over 13,000 sq. mi. (over 8,000,000 acres)
- Elowski, 1980, most recent overview

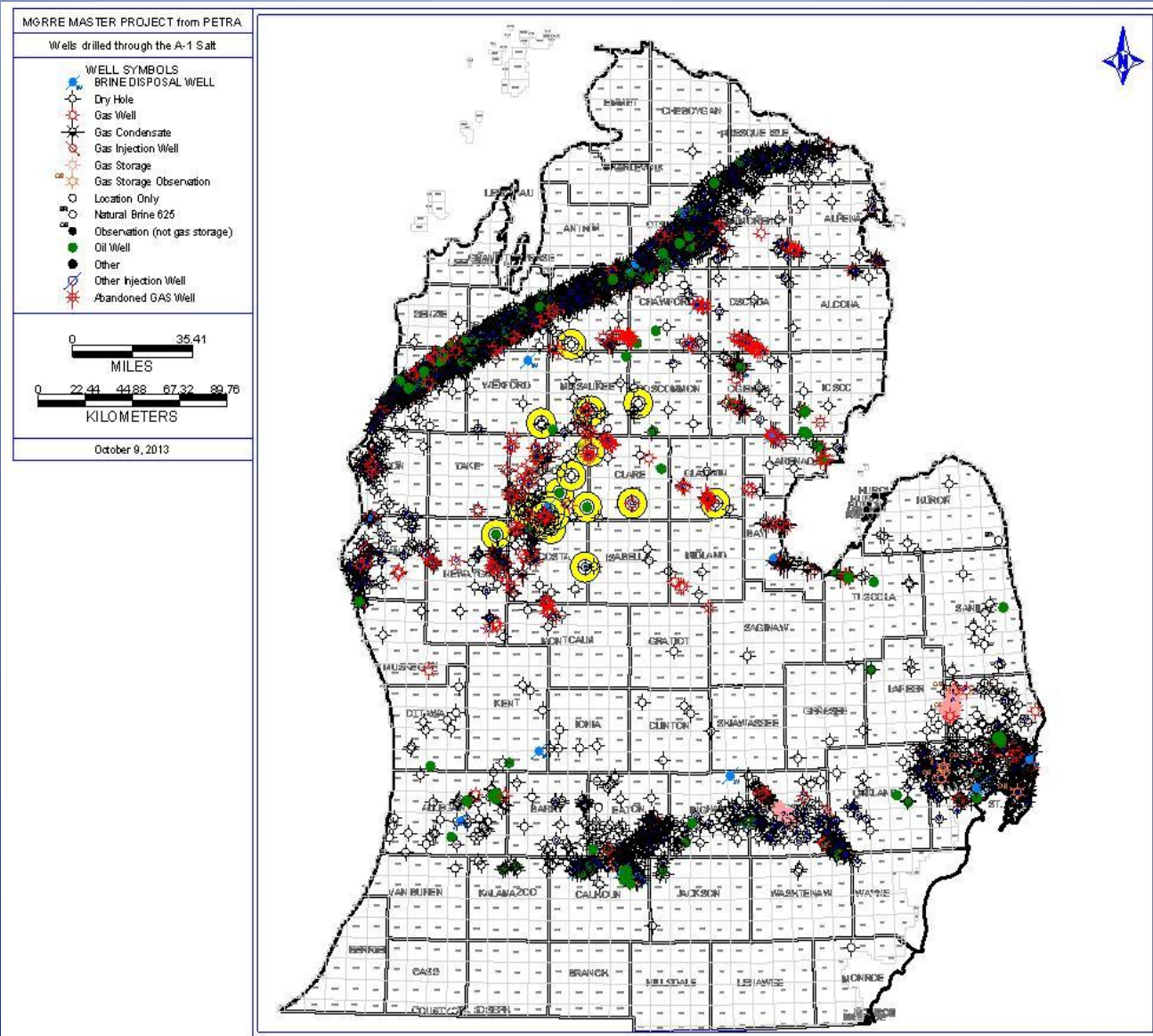


From Anderson and Egleson, 1970

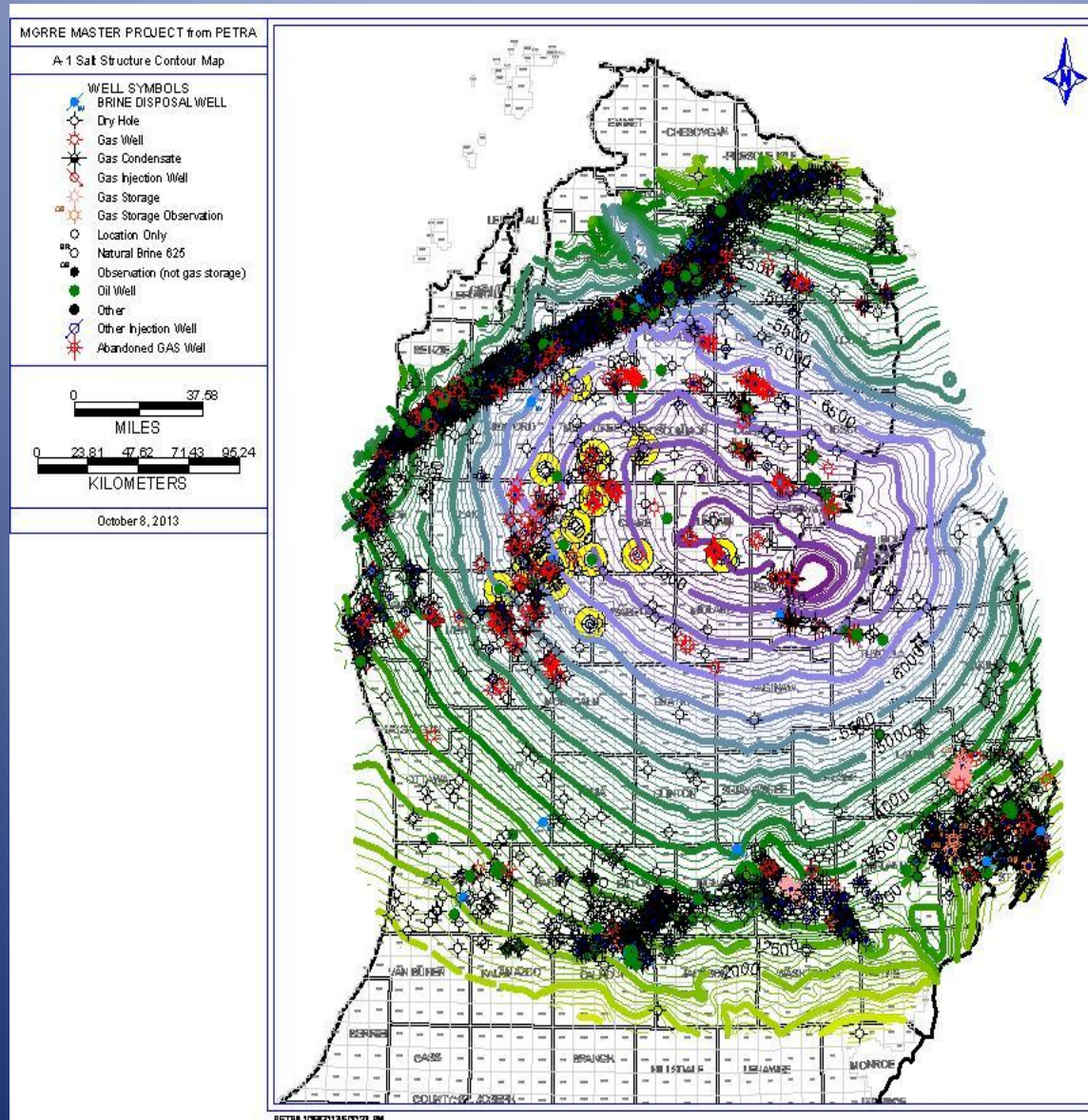
From Matthews, 1970



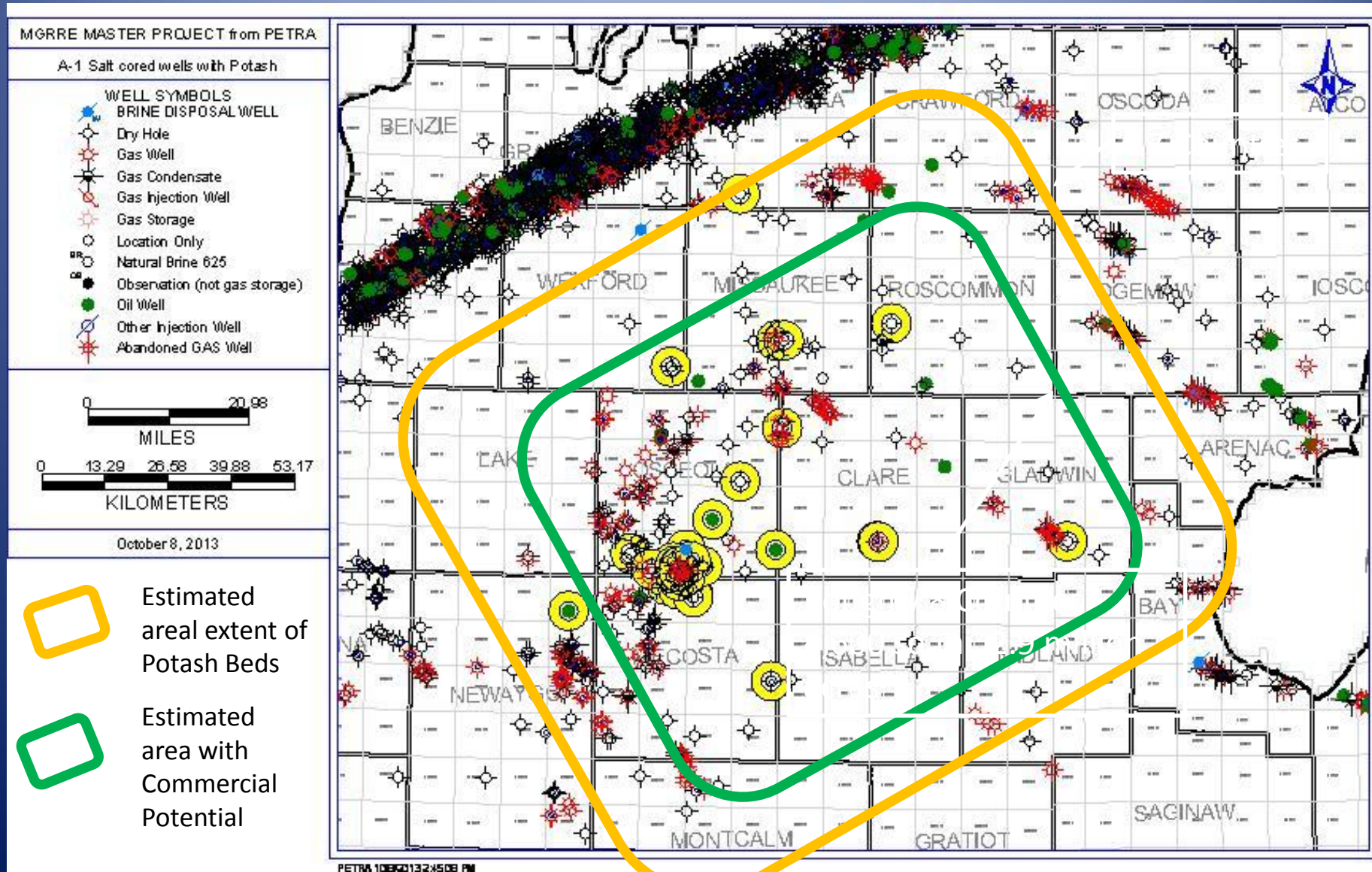
Wells that Penetrate the A-1 Salt In the Michigan Basin



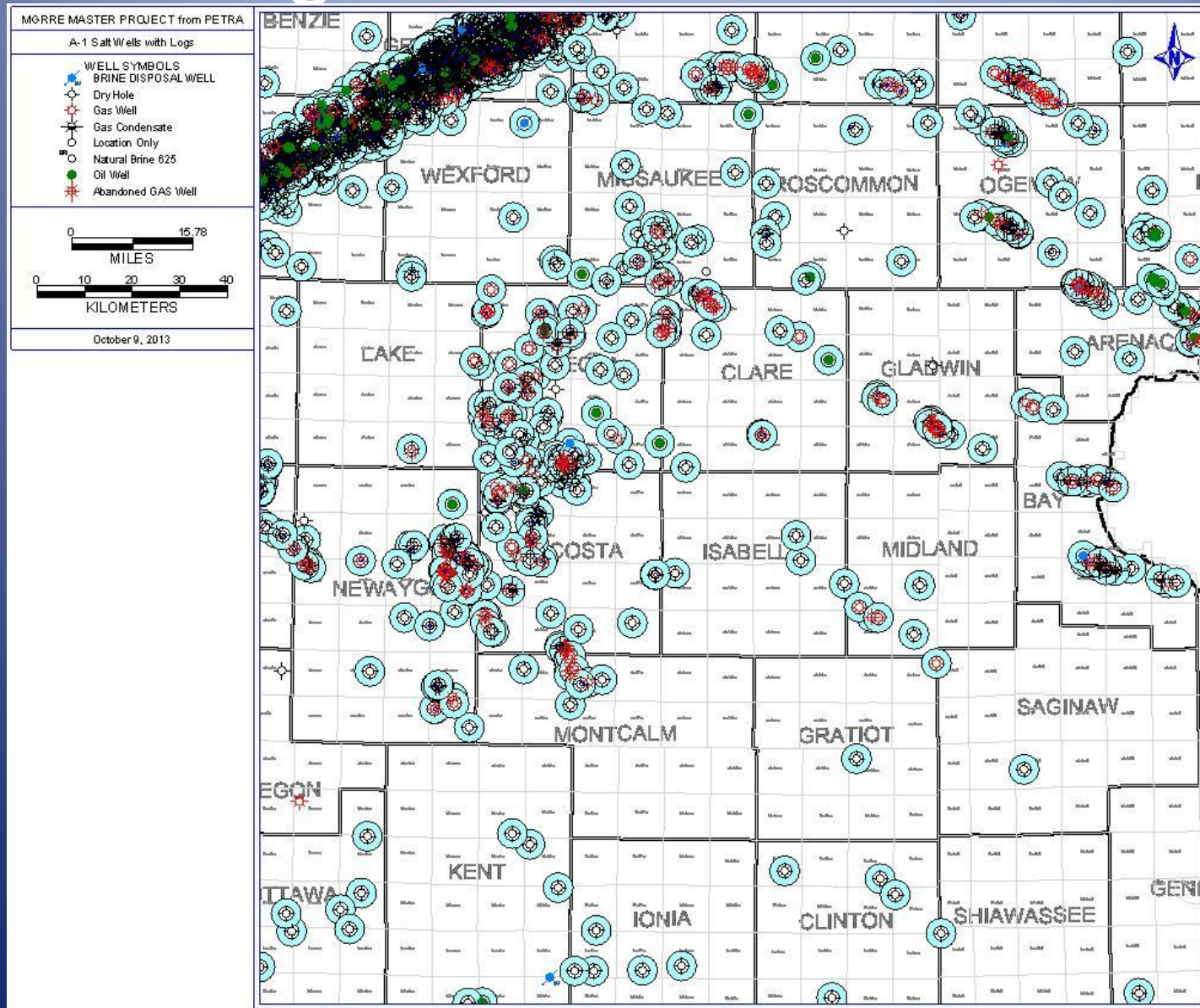
Structural Contour Map on top of Salina A-1 Salt Formation – Depths in Subsea



General Geographic area of occurrence of Potash Beds in Michigan Basin

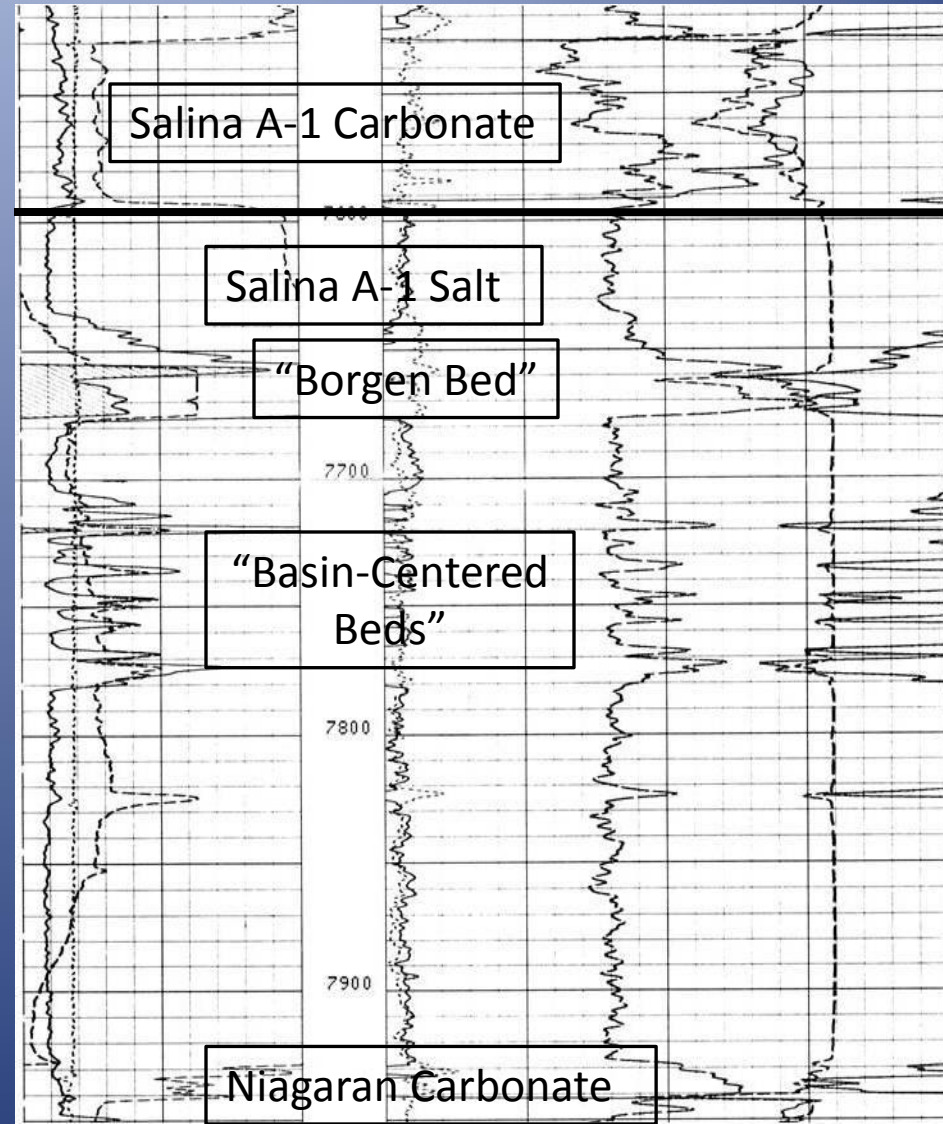


Boreholes with Wireline logs useful for assessing occurrence of Potash Beds



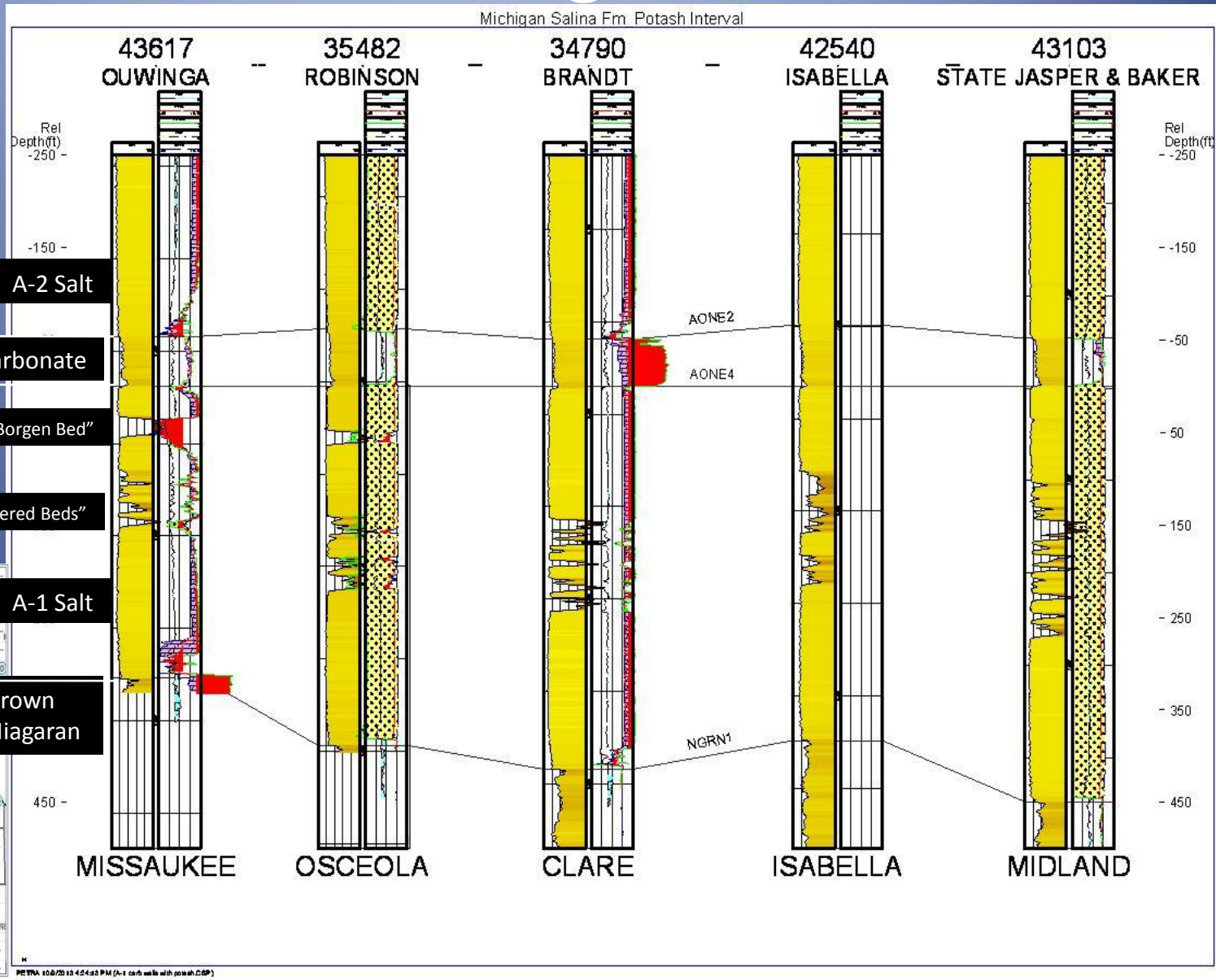
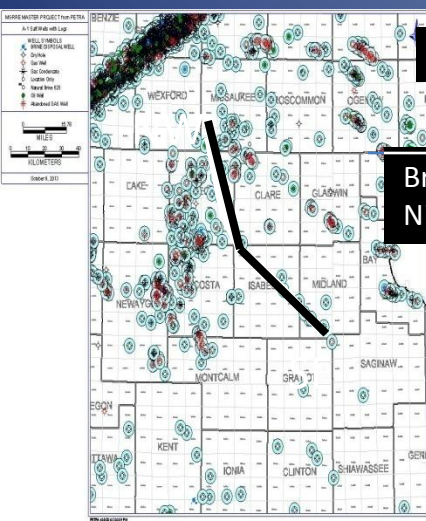
Stratigraphic Occurrence of Potash Beds in Salina A-1 Salt

- Potash is present in two distinct portions of the A-1 Salt
- “Borgen Bed” – Thick (up to 30 ft.) of relatively pure Sylvite, near the top of the formation
- “Basin-Centered Beds” – several to numerous thinner and slightly lower grade Sylvite in the middle or upper third of the formation



NW to SE Cross Section Through Potash Bearing Zone

Michigan
boreholes with
Wireline logs



A-1 Salt Core Collection

- In 2008 the entire core collection from Mosaic Corp. (previously drilled by PPG and IMC) was transferred to Western Michigan University.
- Total of 77 wells comprising 11,380 feet of cored material
- Cores sealed in poly bags and untouched since initial coring and sampling for analyses

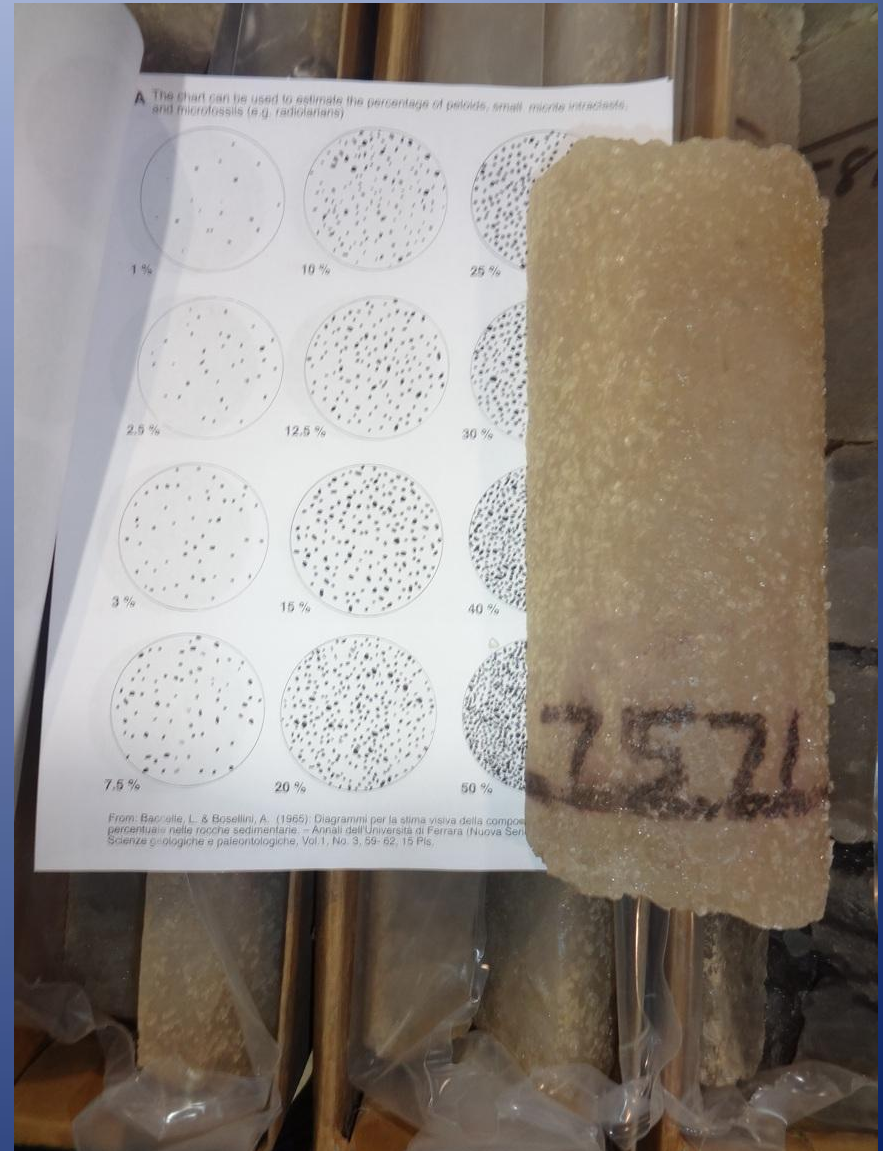


Park # 1-12 Core Showing Primary Depositional Layering in Halite



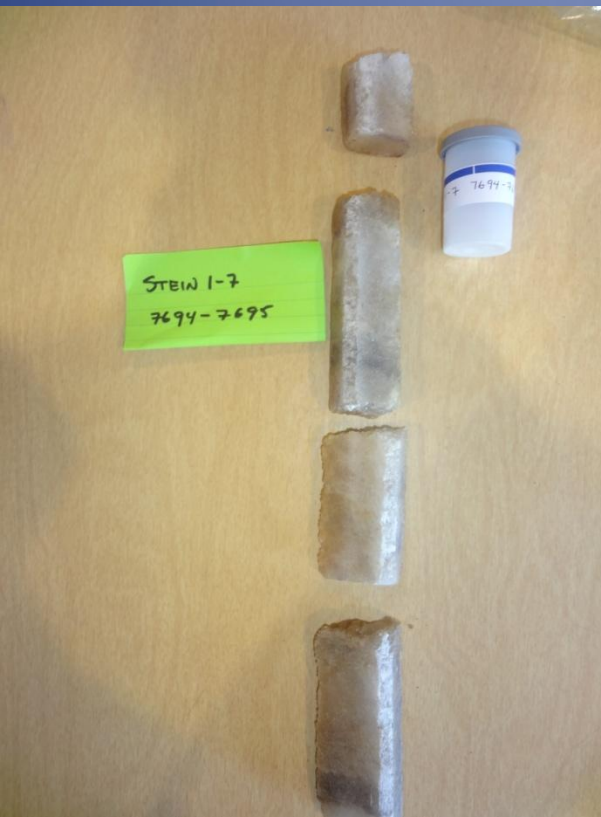
Sylvite occurrence in the A-1 Salt

- May be as pure Sylvite beds interbedded with Halite or as intimately intermixed halite and Sylvite crystals in the same bed
- Visual estimation of Sylvite and Halite percentages can be made on exterior of core due to the relative difference in solubility of the two minerals during the coring process with Halite saturated drilling fluid



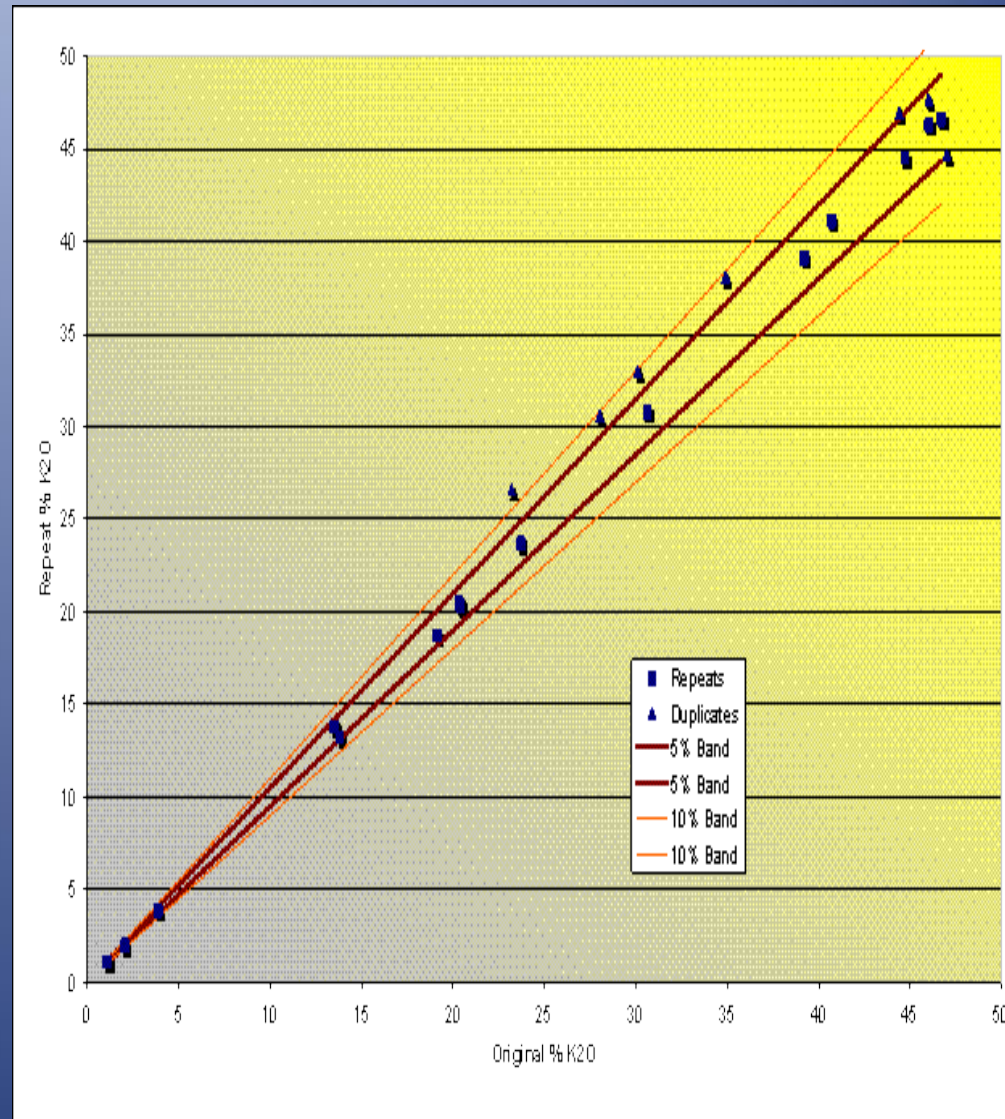
Assay Analysis of Potash Grade

- Some samples of split core portion (1/4 or 1/8) of whole core
- Most samples were from powder drilled from fresh core surface in the interior of a split core
- Half meter to one meter sampled continuously

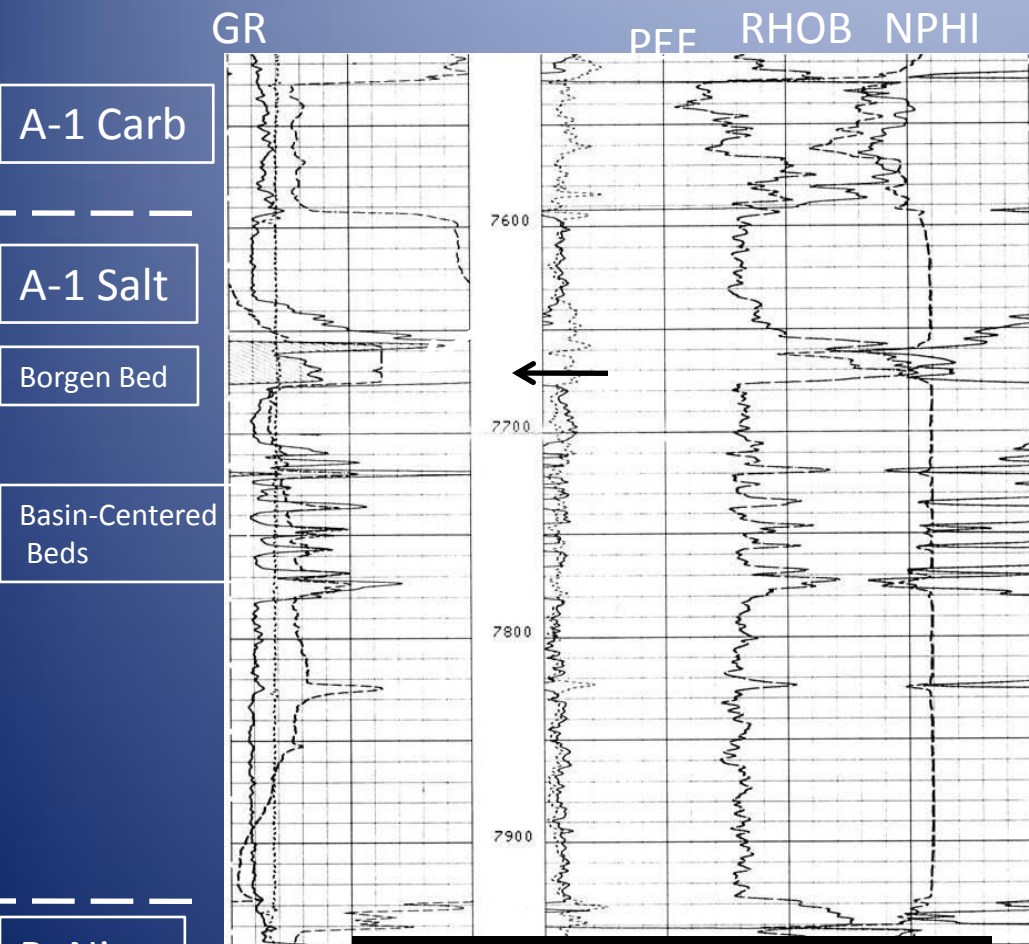


Quality Control on Analyses

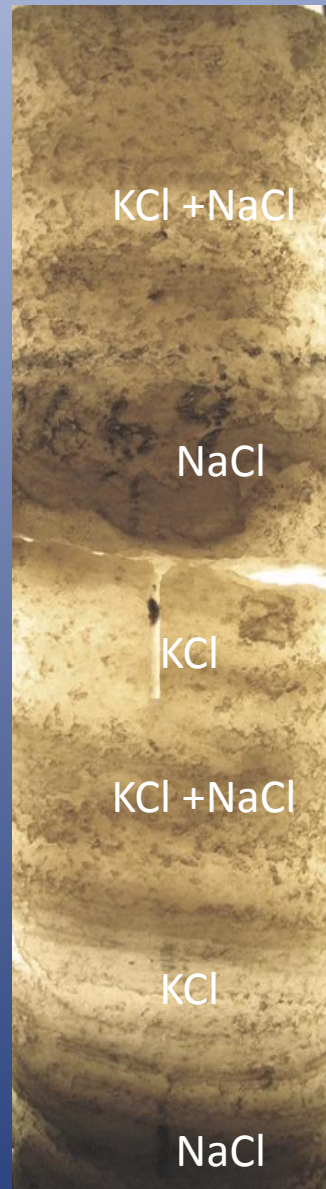
- Replicate and duplicate samples were analyzed
- Solid core chunks as well as drilled powder samples from the same interval were compared



Potash from “Borgen Bed” Interval



Willmet-Gray #1-31
Osceola Co. 31-17N-8W
P#35800
A-1 Evap Core: 7593-7854 ft

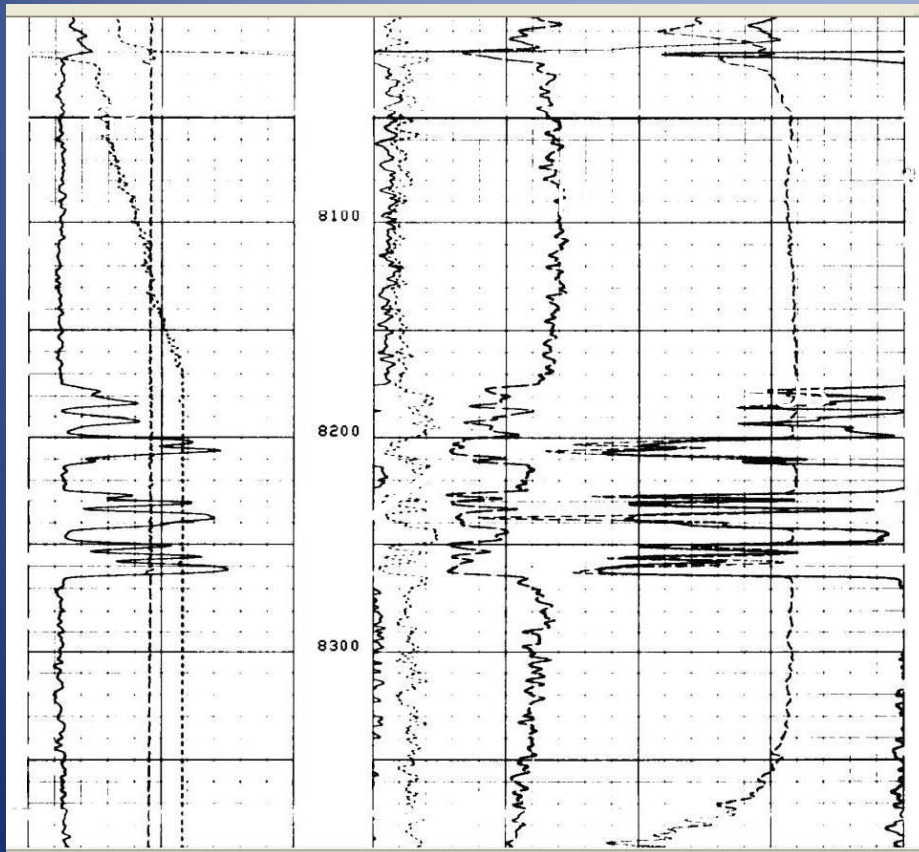


Visual Volume estimate: This foot long piece of core averages approximately 52.1% KCl or 32.4% K_2O (Average Borgen Bed assay is 58.7% KCl)

3.5" - 50:50% - KCl+NaCl - 14.58
 1.5" - 100% - NaCl - 0.00
 1" - 50:50% - KCl+NaCl - 4.17
 1.75" - 100% - KCl - 14.58
 2.5" - 50:50% - KCl+NaCl - 10.41
 1" - 100% - KCl - 8.33
 1" - 100% - NaCl - 0.00

Cored interval shown:
 7668.5-7669.5

Portion of Core through Basin-Centered Beds in Osceola County



**WOLVERINE OIL AND GAS –
MICHIGAN CONSOL. GAS CO. #1-13
OSCEOLA CO. 13-17N-7W
P# 35832
A-1 EVAP CORE: 8016-8272 FT.**

Visual Volume Estimate:

This eight inch piece is
approximately 37.5% KCl or
23.7% K_2O

1" - 50:50% – KCl+NaCl – 6.25

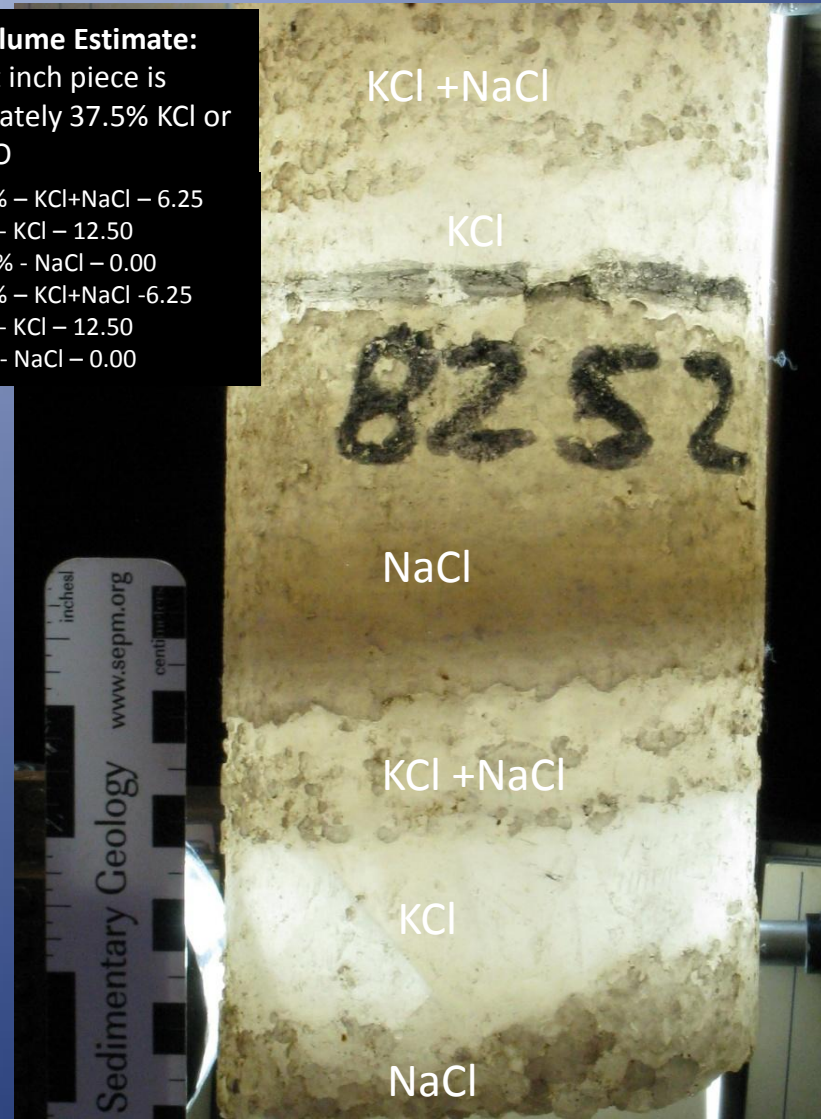
1" – 100% - KCl – 12.50

2.5" - 100% - NaCl – 0.00

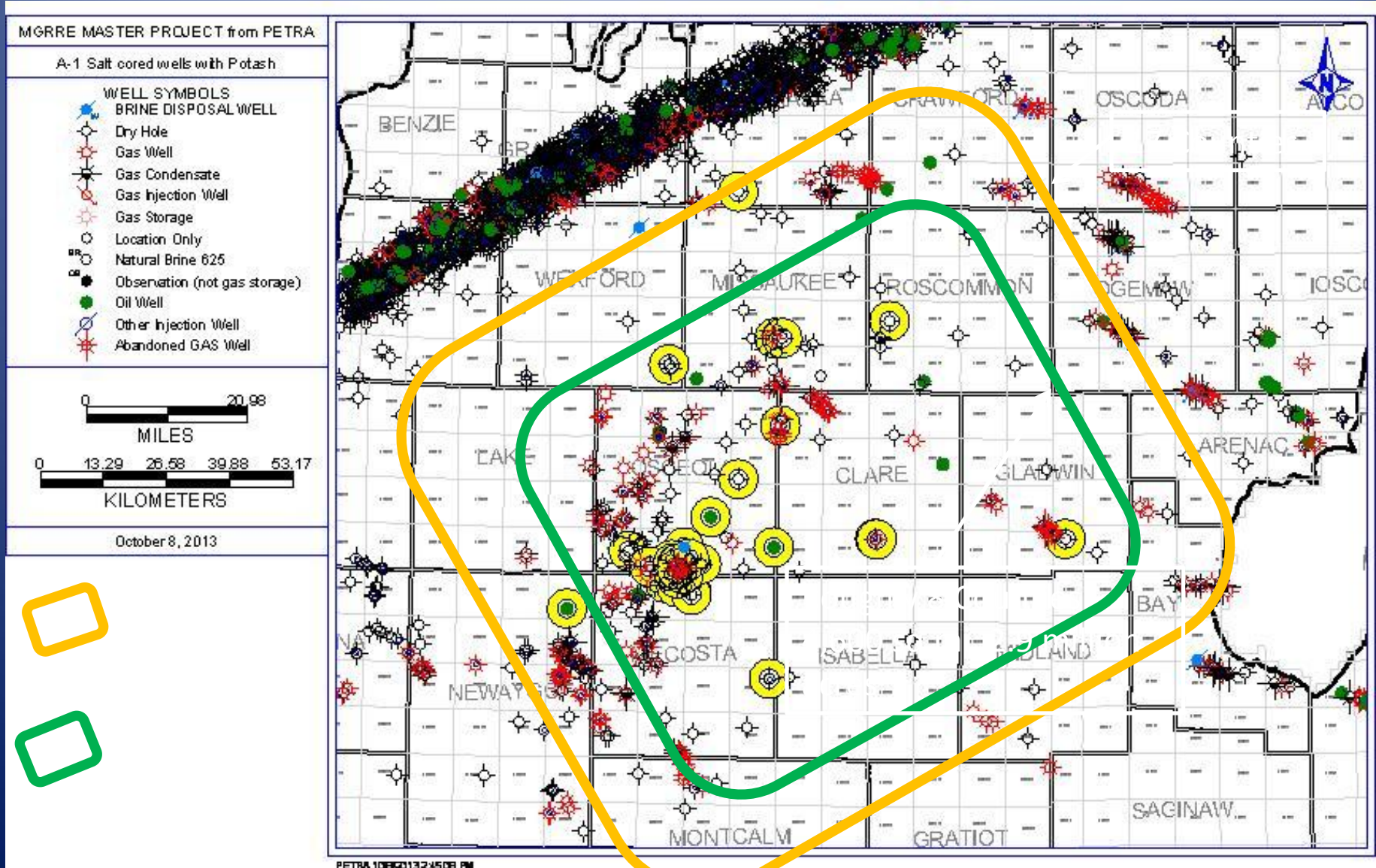
1" - 50:50% – KCl+NaCl – 6.25

1" – 100% - KCl – 12.50

1" - 100% - NaCl – 0.00



General Geographic area of occurrence of Potash Beds in Michigan Basin



Summary of Michigan Potash

- Occurs only in the Salina A-1 Salt in the center of Michigan basin,
- 8 counties have thickest, many areas may have recoverable deposits
 - Missaukee, Roscommon, Clare, Osceola, Gladwin, Midland, Isabella, Mecosta (Approximately 2,900,000 gross acres)
- Two main target horizons – Estimated through volumetric observations of %KCL
 - “Borgen Bed” - Generally one continuous bed 10 to 30 feet thick, Average estimated volume calculation from core observation:
 - 55% KCL or 35% K_2O – Primarily NW side of Basin
 - Basin-Centered Beds – Numerous thin beds (inches to a few feet thick) gross interval 70 to 150 feet thick, net log measured potash thickness 40-70 feet Average estimated volume calculation from core observation:
 - 43.8% KCL or 27.7% K_2O
- Comparison to other world potash production grades
 - Canada – 18% – 24% K_2O
 - Utah – 24% K_2O
 - New Mexico – 8% - 22% K_2O
 - Russia – 18% - 22% K_2O